Experimental Hadronic Physics at Florida State

Prof. Volker Credé

Prof. Paul Eugenio & Dr. Alexander Ostrovidov

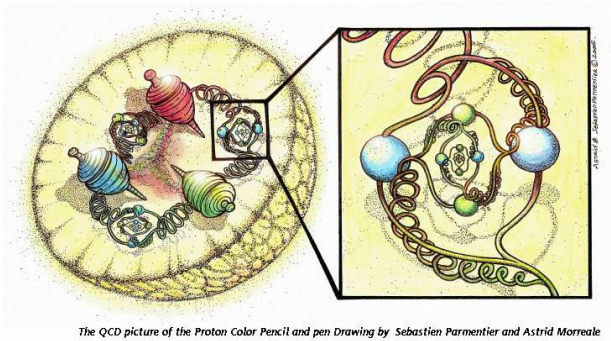
and graduate students N. Sparks, A. Wilson, C. Hanretty, S. Park, C. Bookwalter, M. Saini

and our undergraduate students Peter Morales, Matthew Szmaida, Dennice Roberts, Tobias Neumann

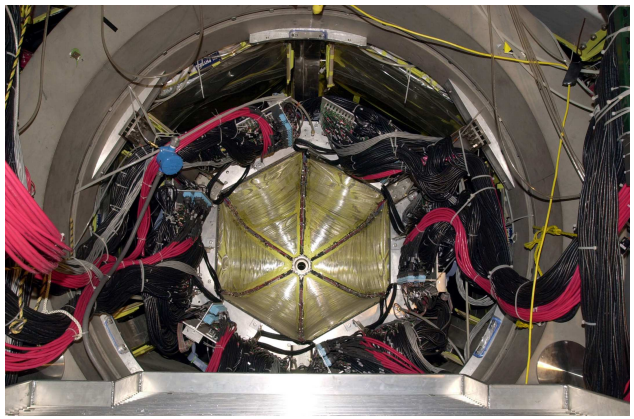
Graduate Student Seminar Series

October 1, 2010

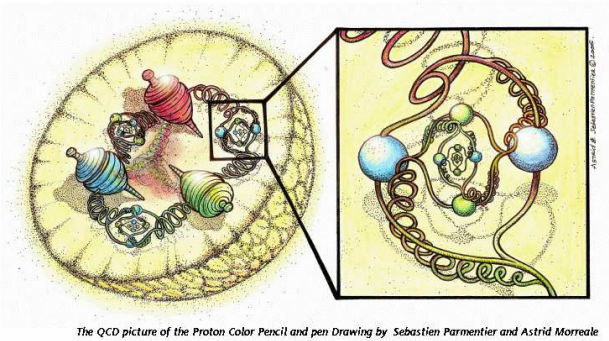
Outline



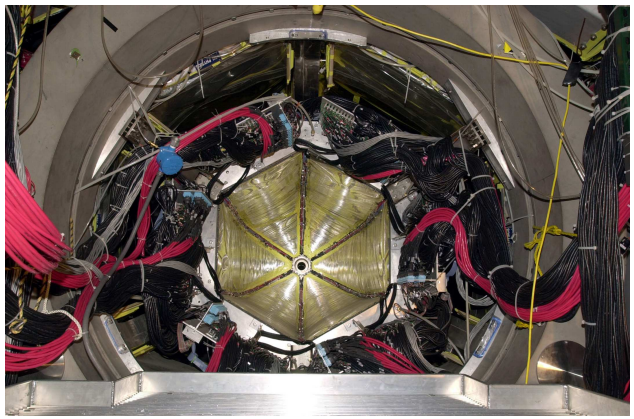
The QCD picture of the Proton Color Pencil and pen Drawing by Sebastien Parmentier and Astrid Morreale



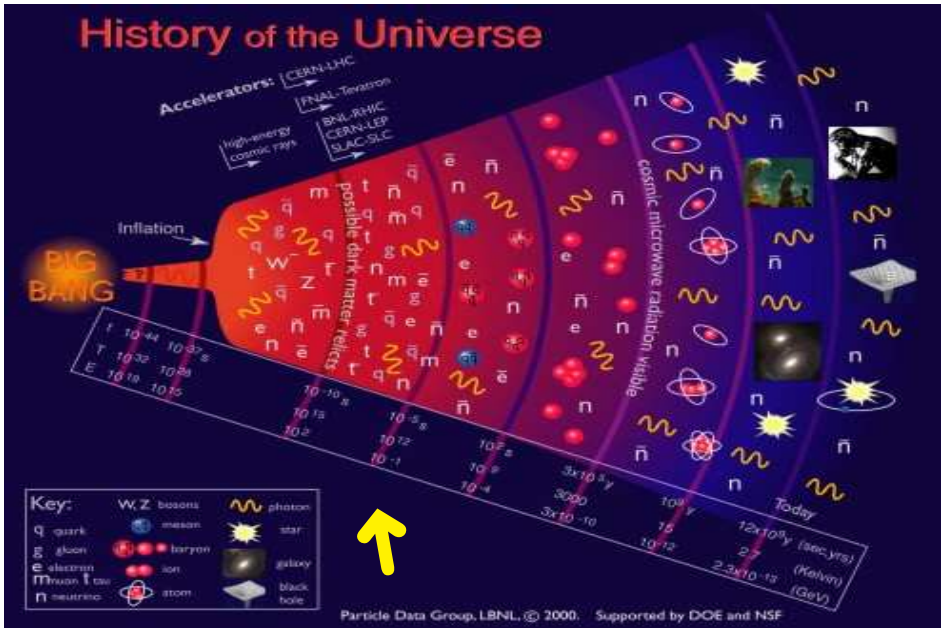
Outline



The QCD picture of the Proton Color Pencil and pen Drawing by Sebastien Parmentier and Astrid Morreale

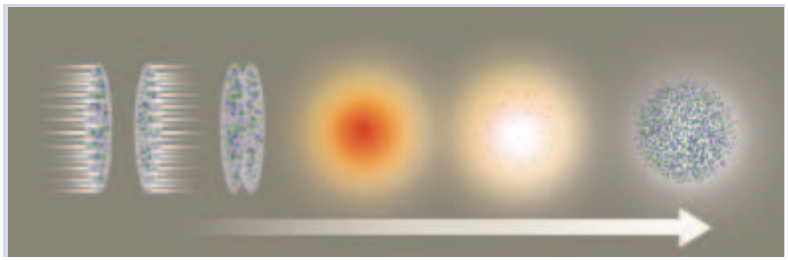


Quark Gluon Plasma

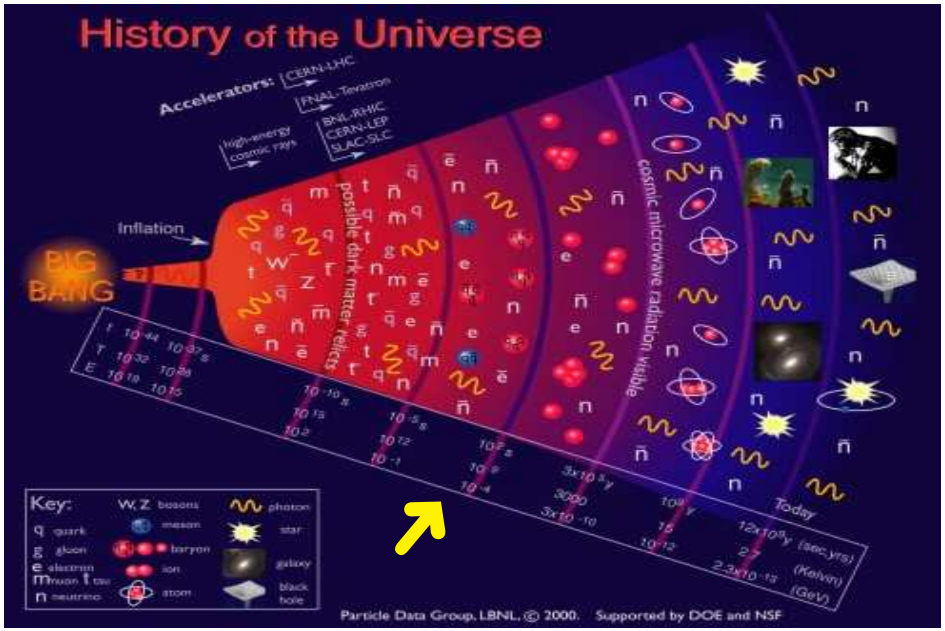


For a period from about 10^{-12} s to 10^{-6} s, the universe contained a plasma of quarks, anti-quarks, and gluons.

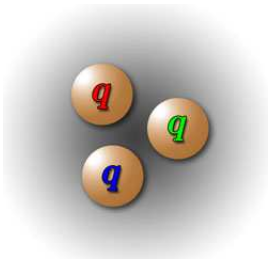
Relativistic Heavy Ion Colliders are trying to produce this state of matter in collisions:

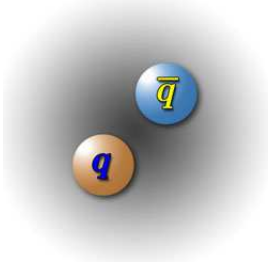


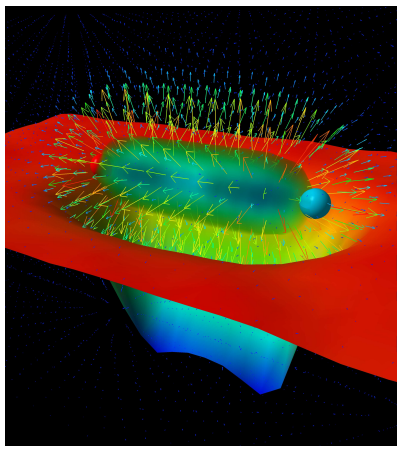
Confinement



From about 10^{-6} s on, all quark and anti-quarks became confined inside of hadronic matter. Only protons and neutrons remained after about 1 s.







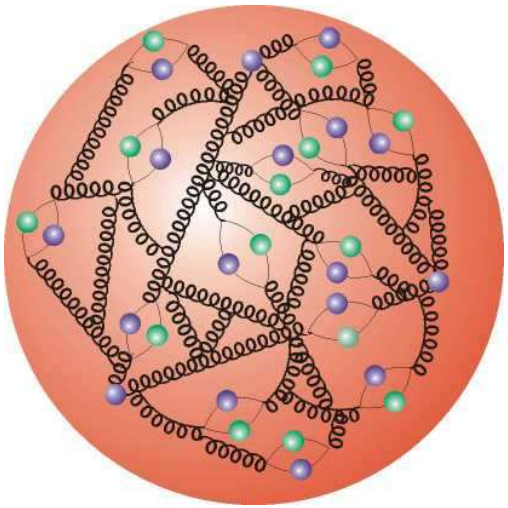
What is the origin of confinement, describing $\sim 99\,\%$ of observed matter?

Quantum Chromodynamics (QCD)

... is the theory of strong interactions; the strong force describes the interactions of quarks and gluons making up hadrons.

QCD enjoys two important properties:

1. **Asymptotic Freedom**
   In high-energy reactions, quarks and gluons interact very weakly.



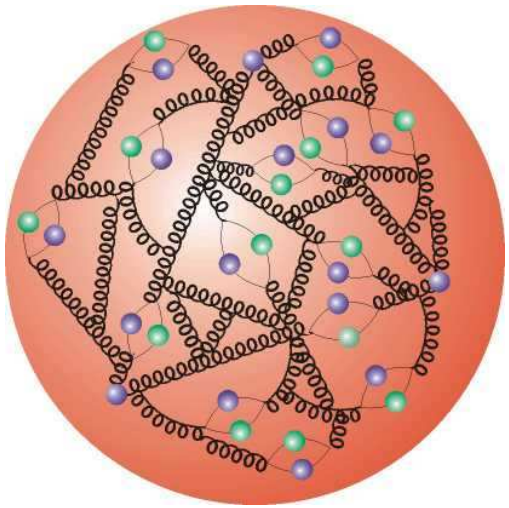
The inside of the proton at high energies – a “dense soup” of quarks and gluons.

Quantum Chromodynamics (QCD)

... is the theory of strong interactions; the strong force describes the interactions of quarks and gluons making up hadrons.

QCD enjoys two important properties:

1. **Asymptotic Freedom**
   In high-energy reactions, quarks and gluons interact very weakly.



Good quantitative tests of perturbative QCD are:

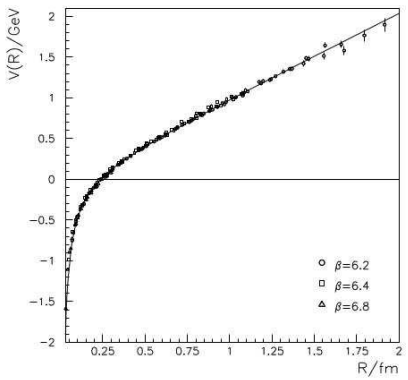
- Running QCD coupling
- Scaling violation in (un)polarized DIS
- Jet cross sections in colliders
- Heavy-quark production in colliders

Quantum Chromodynamics (QCD)

... is the theory of strong interactions; the strong force describes the interactions of quarks and gluons making up hadrons.

QCD enjoys two important properties:

1. **Asymptotic Freedom**
   In high-energy reactions, quarks and gluons interact very weakly.
2. **Confinement**
   Force between quarks does not diminish as they are separated.



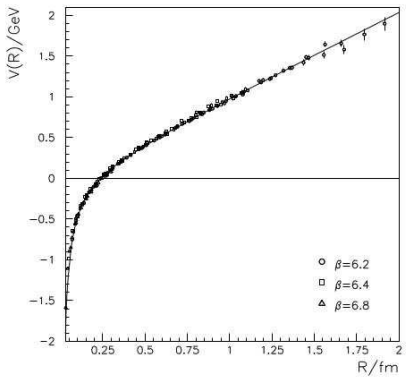
No free quarks!

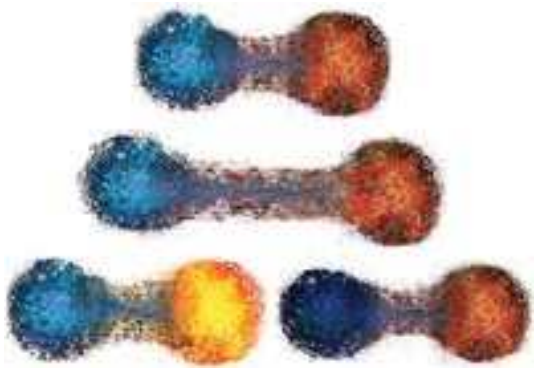
Quantum Chromodynamics (QCD)

... is the theory of strong interactions; the strong force describes the interactions of quarks and gluons making up hadrons.

QCD enjoys two important properties:

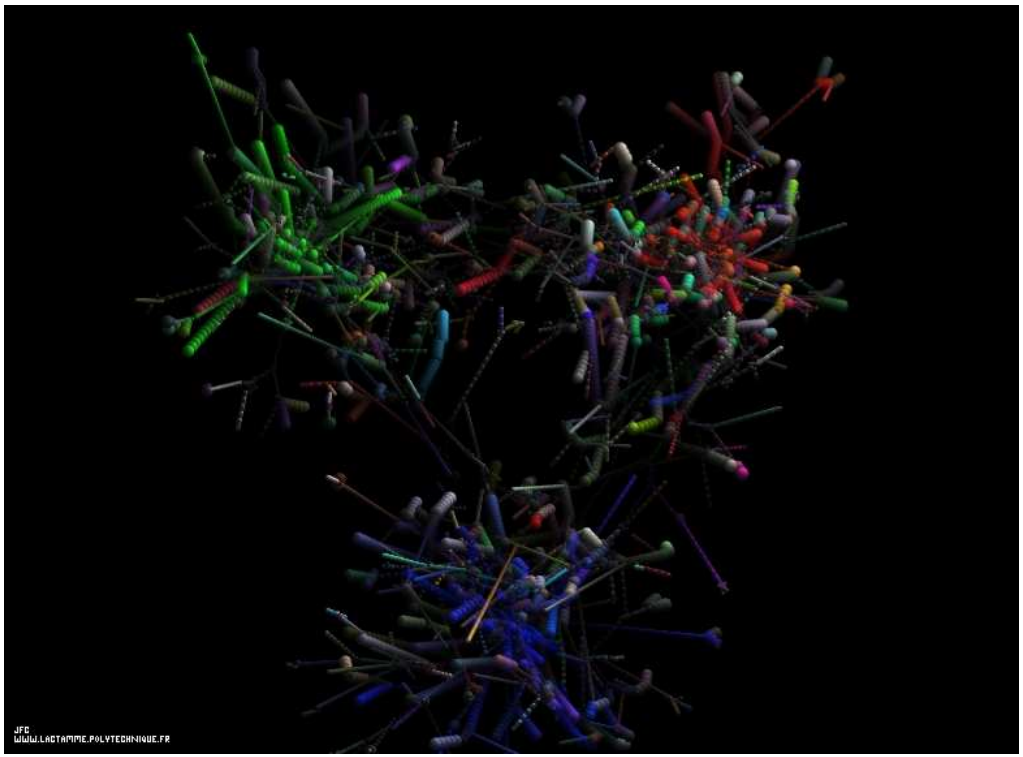
1. **Asymptotic Freedom**
   In high-energy reactions, quarks and gluons interact very weakly.
2. **Confinement**
   Force between quarks does not diminish as they are separated.





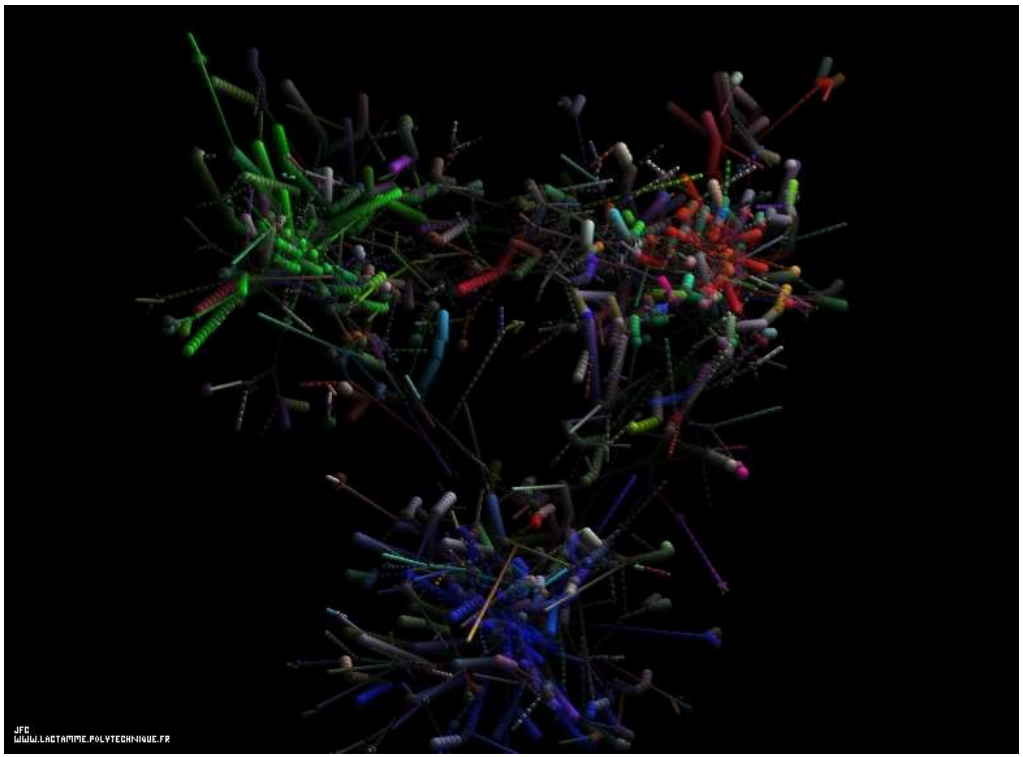
Non-Perturbative QCD

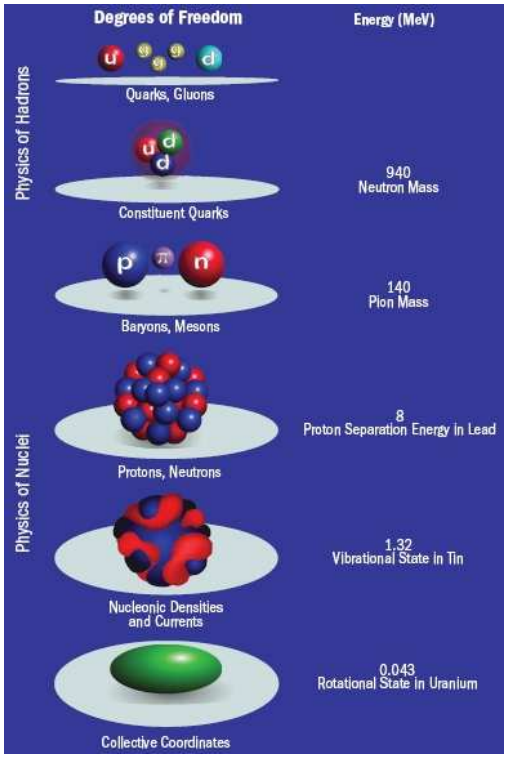
Strong interaction processes at larger distances and at small (soft) momentum transfers belong to the realm of non-perturbative QCD:



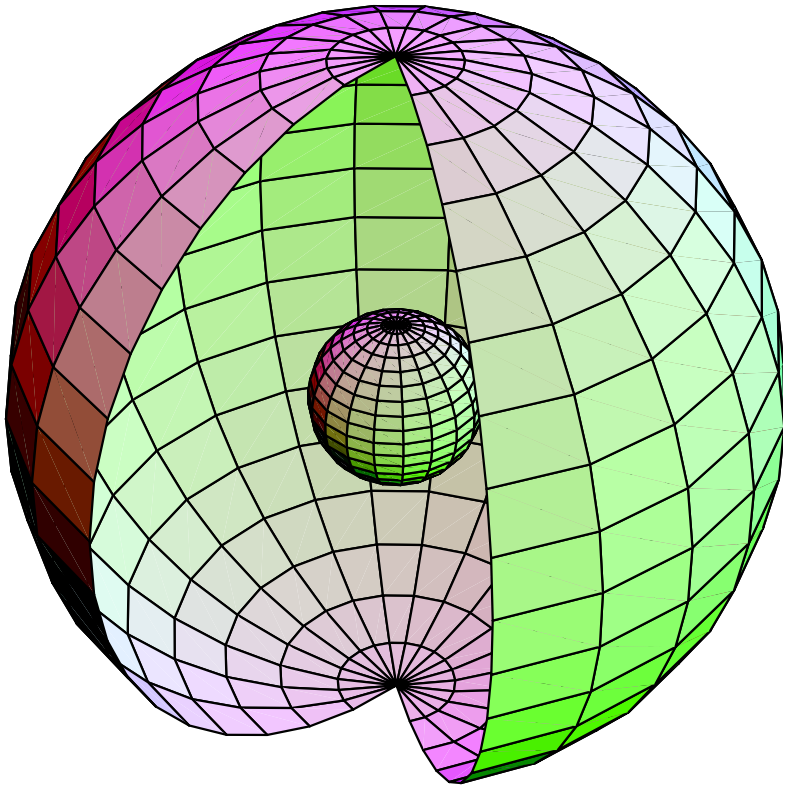
Non-Perturbative QCD

Strong interaction processes at larger distances and at small (soft) momentum transfers belong to the realm of non-perturbative QCD:





Non-Perturbative QCD



Courtesy of Craig Roberts, Argonne

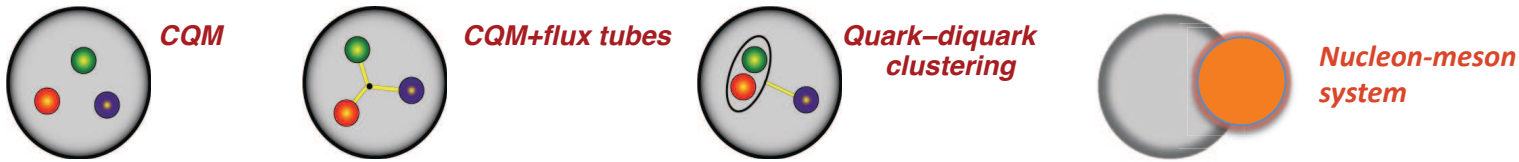
How does QCD give rise to hadrons?

Interaction between quarks unknown throughout > 98 % of a hadron's volume

The Issues with Hadrons

1. **The Baryons**

   What are the fundamental degrees of freedom inside of a proton and a neutron? How do they change with varying quark masses?



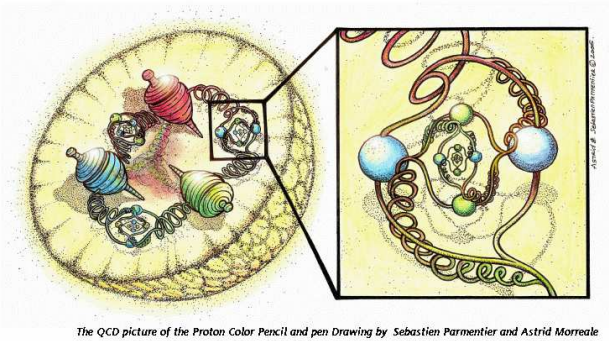
2. **Mesons**

   What is the role of glue in a quark-antiquark system and how is this related to the confinement of QCD?

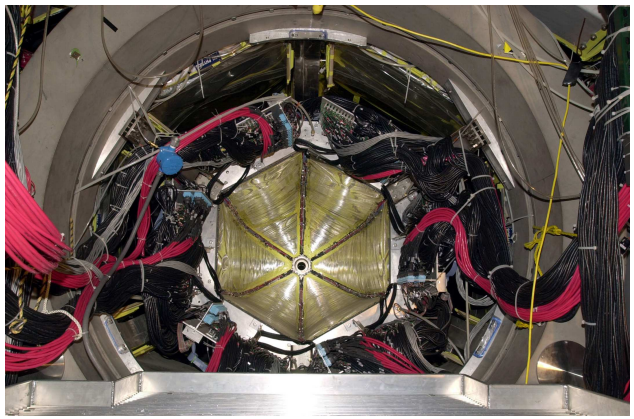
   What are the properties of predicted states beyond simple quark-antiquark systems (hybrid mesons, glueballs, ...)?

   ➜ Need to map out new states: BES III, COMPASS, Panda@GSI, GlueX@JLab, ...

Outline



The QCD picture of the Proton Color Pencil and pen Drawing by Sebastien Parmentier and Astrid Morreale



One of the Goals of the N^* Program ...

Search for *missing* or yet unobserved resonances

Quark models predict many more baryons than have been observed

	****	***	**	*
N Spectrum	11	3	6	2
Δ Spectrum	7	3	6	6

➜ according to PDG
(J. Phys. G **37**, 075021 (2010))

➜ little known
(many open questions left)

Are the states missing because our pictures do not capture the correct degrees of freedom?

One of the Goals of the N^* Program ...

Search for *missing* or yet unobserved resonances

Quark models predict many more baryons than have been observed

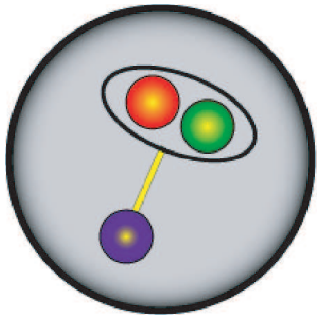
	****	***	**	*
N Spectrum	11	3	6	2
Δ Spectrum	7	3	6	6

➜ according to PDG
(J. Phys. G **37**, 075021 (2010))

➜ little known
(many open questions left)

Possible solutions:

1. Quark-diquark structure



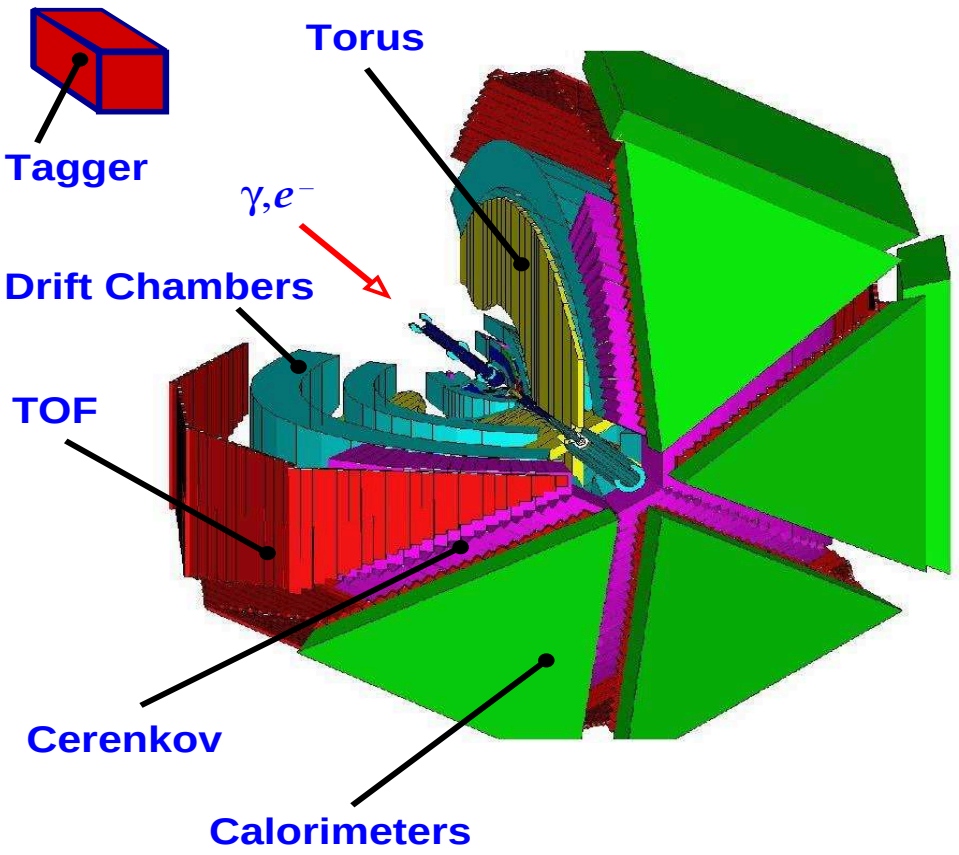
one of the internal degrees of freedom is frozen

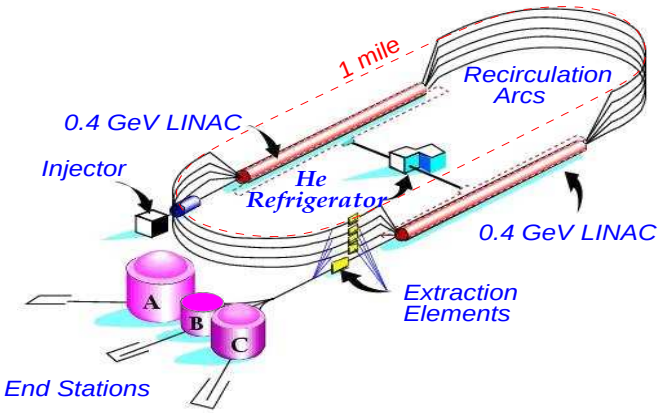
2. Have not been observed, yet

Nearly all existing data result from πN scattering experiments

➜ If the missing resonances did not couple to Nπ, they would not have been discovered!!

CLAS Spectrometer





CHARACTERISTICS:

Electron Coverage: $\theta : 15\text{–}50^{o}$

Hadron Coverage:

$\theta : 15\text{–}140^{o}$, $\phi : 80\%\ 2\pi$

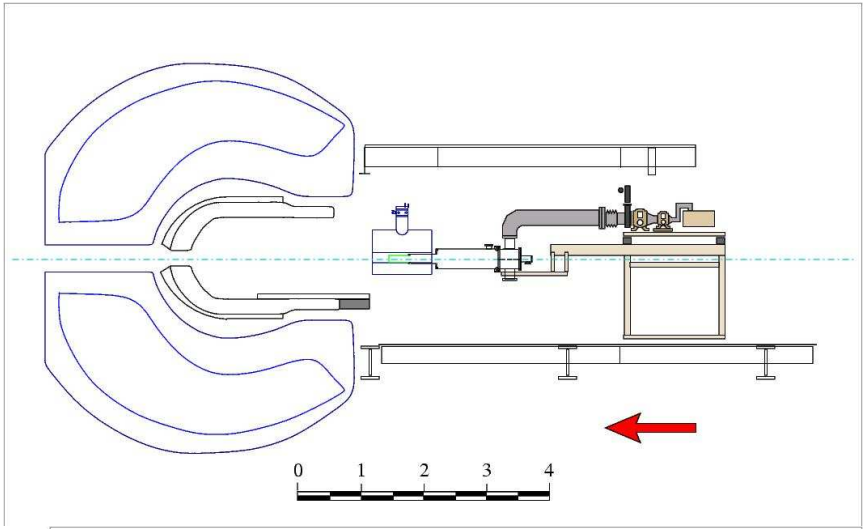
Resolution : $\Delta p/p \sim 1\text{–}2\%$
$\Delta\theta, \Delta\phi \sim 2\ mrad$

$$\mathcal{L} = 1 \times 10^{34}\ cm^{-2} sec^{-1}$$
$$\mathcal{F}_{\gamma} = 1 \times 10^{7}/s$$

Double-Polarization Experiments

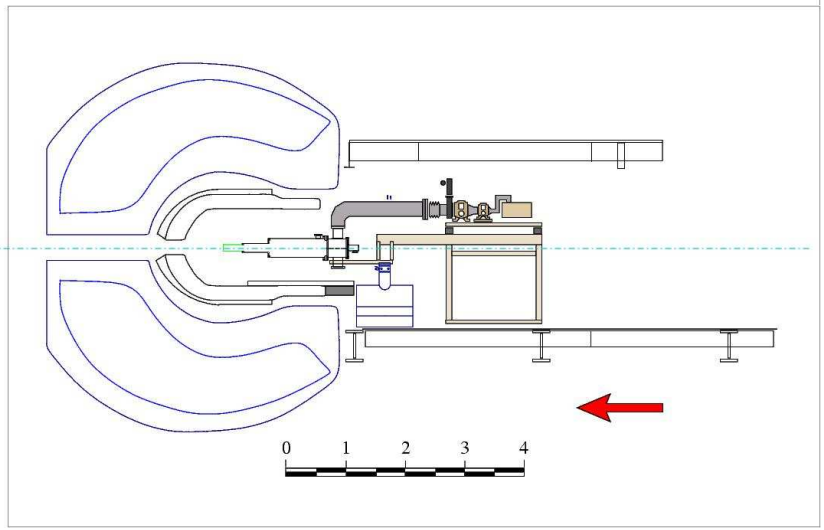
Polarizing Mode

- Microwaves, 5 T magnet ON
- Temperature 0.5 K
- Photon Beam OFF

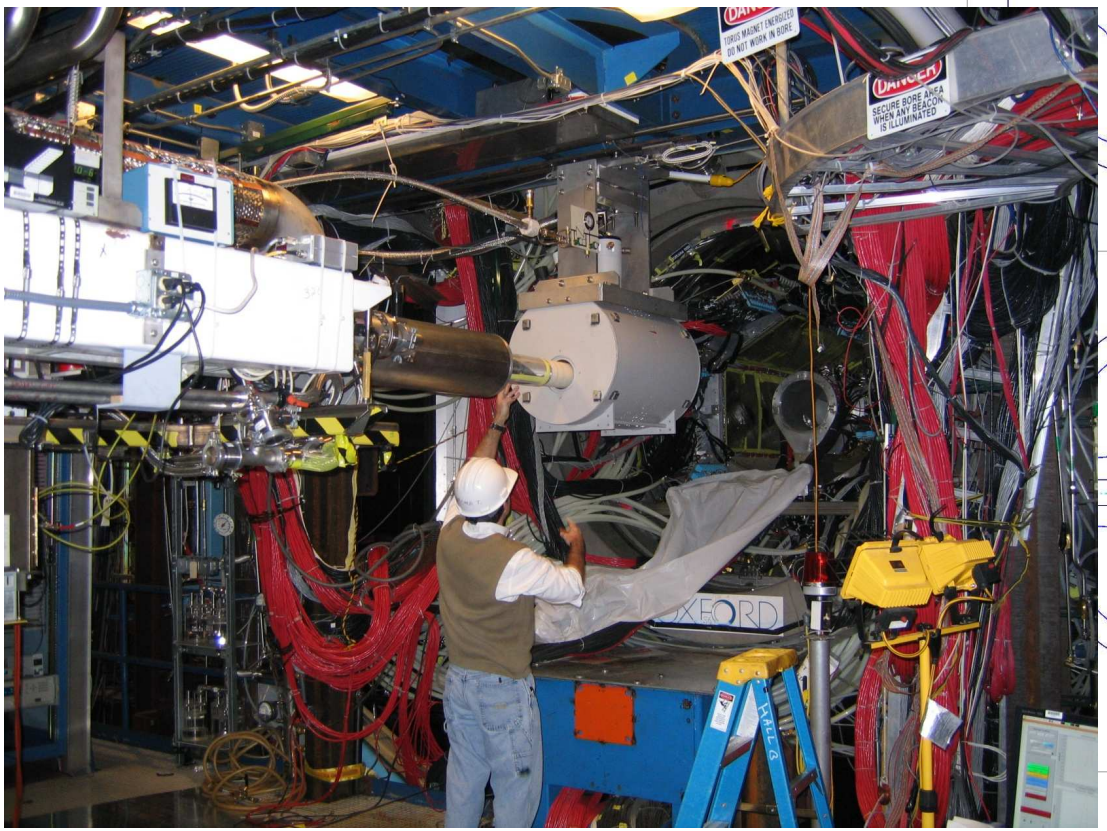


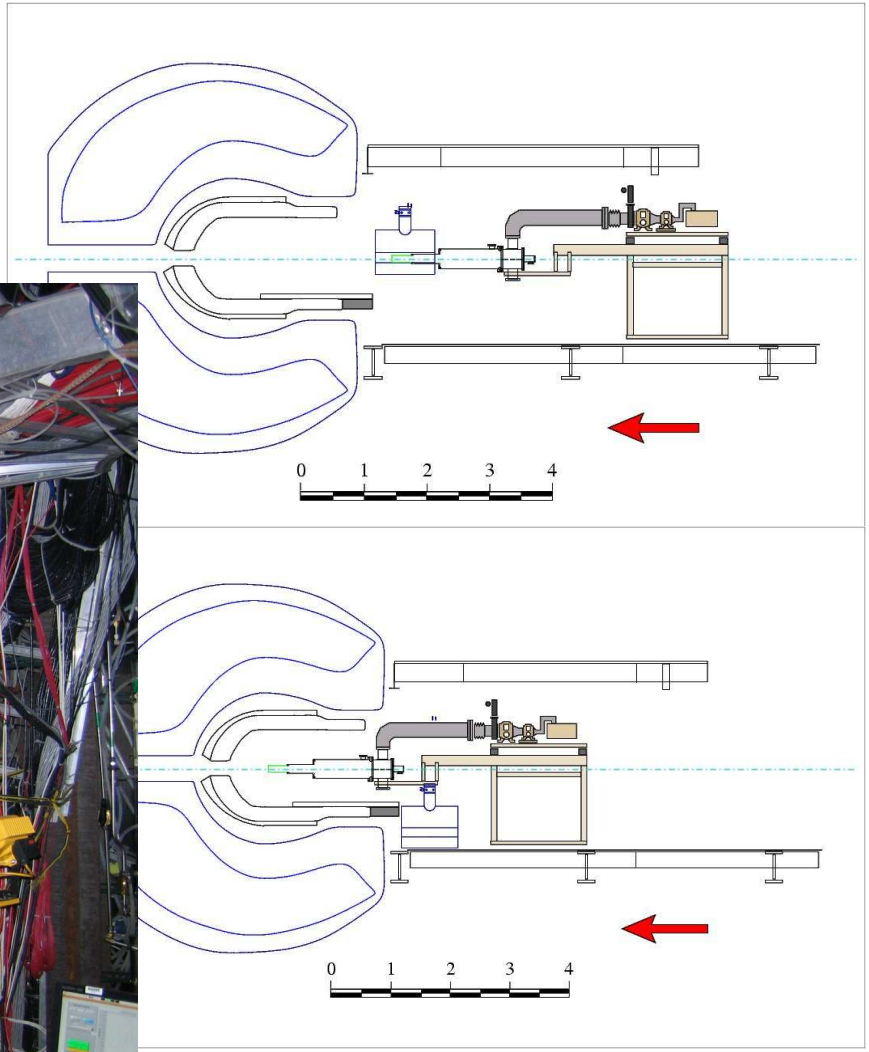
Frozen-Spin Mode

- Microwaves, 5 T magnet OFF
- 0.5 T holding magnet ON
- Temperature $\sim$ 0.05 K
- Photon Beam ON

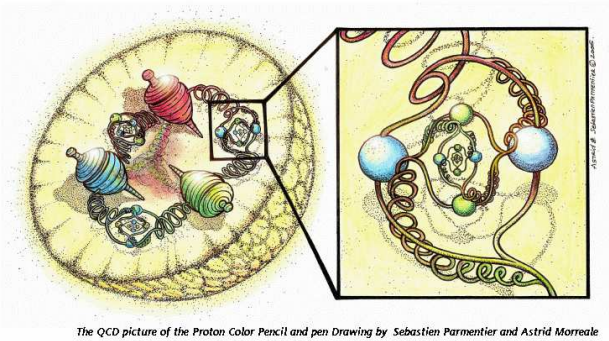


Double-Polarization Experiments

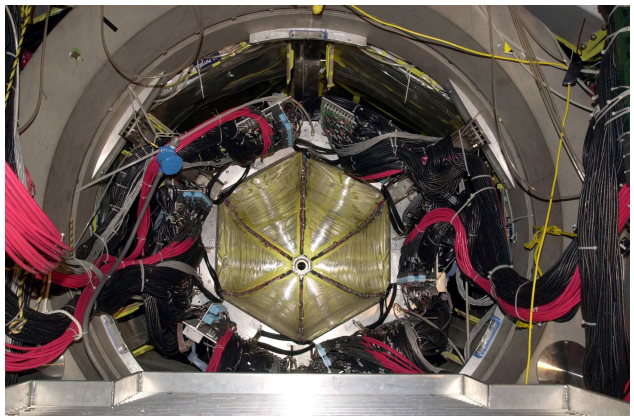




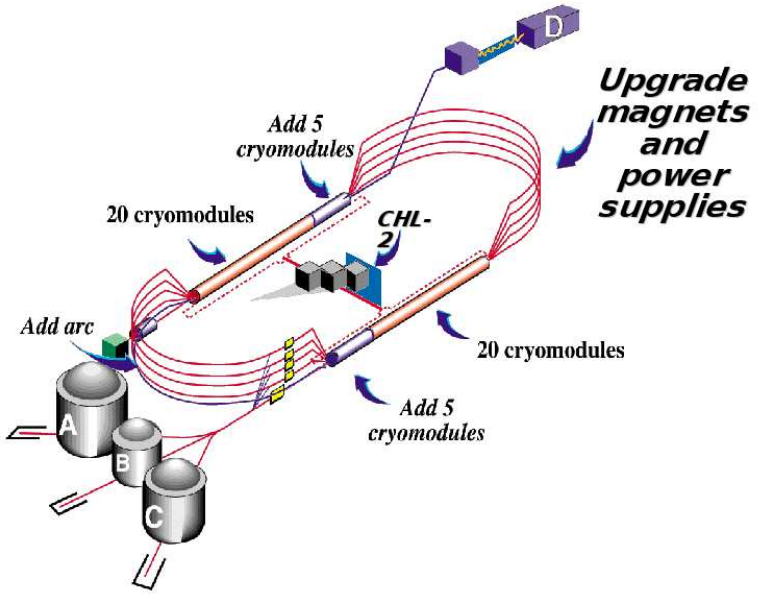
Outline



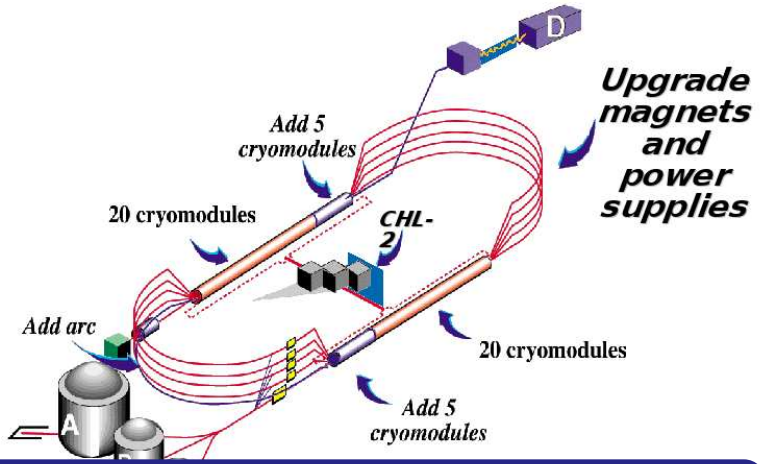
The QCD picture of the Proton Color Pencil and pen Drawing by Sebastien Parmentier and Astrid Morreale



The GlueX Experiment at Jefferson Laboratory



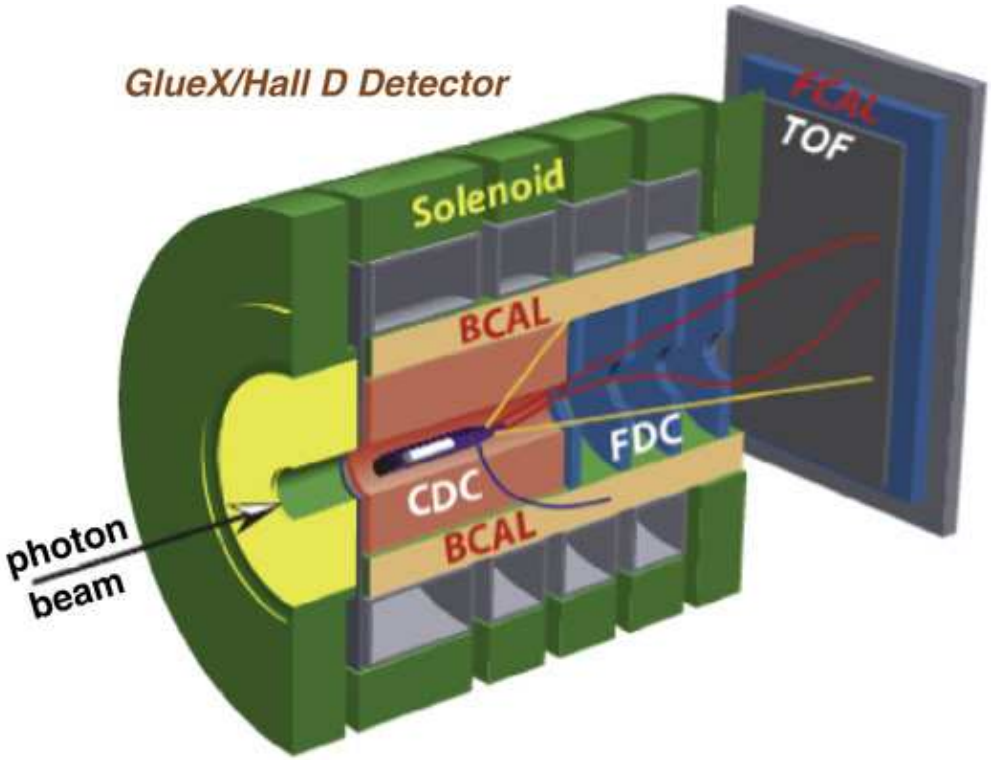
The GlueX Experiment at Jefferson Laboratory

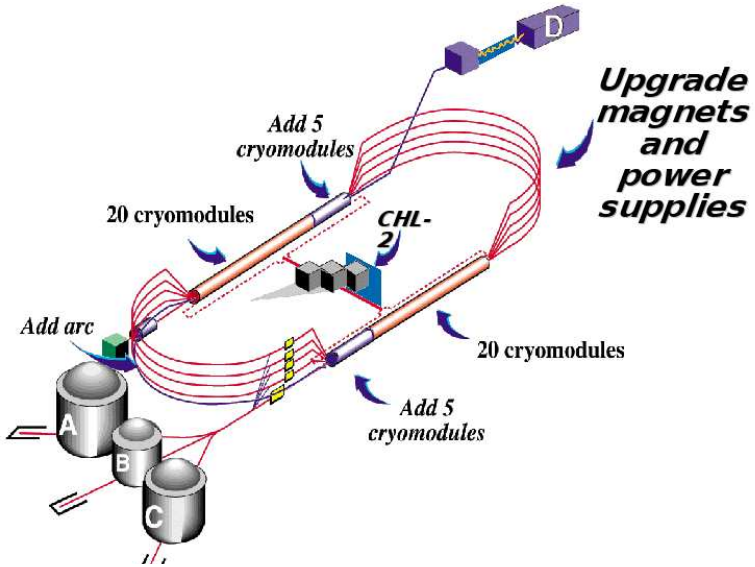


The 12 GeV upgrade is under construction.

- Construction of Hall-D broke ground in April 2009.
- Construction of the GlueX detector has started.
- Current plans call for the first beam in HallD/GlueX in late 2014.

The GlueX Experiment at Jefferson Laboratory

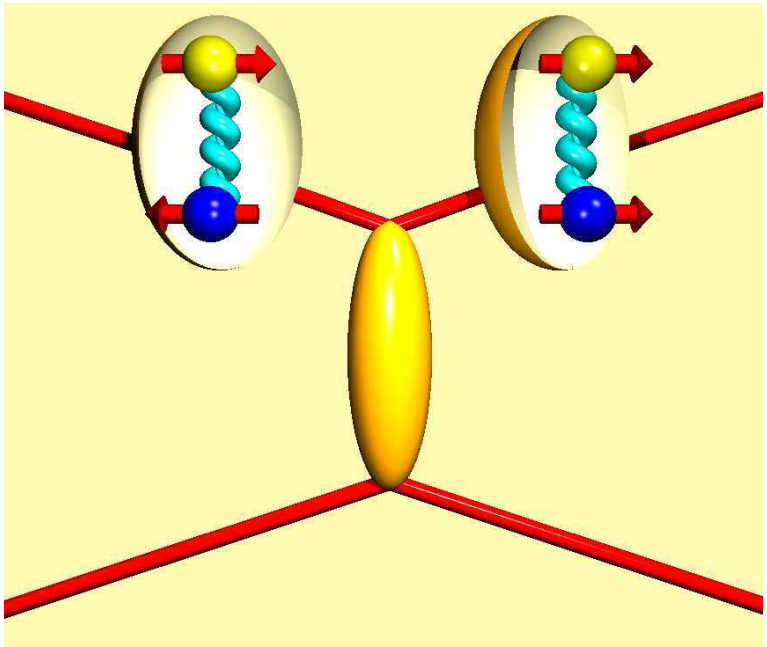




TOF being built at FSU!

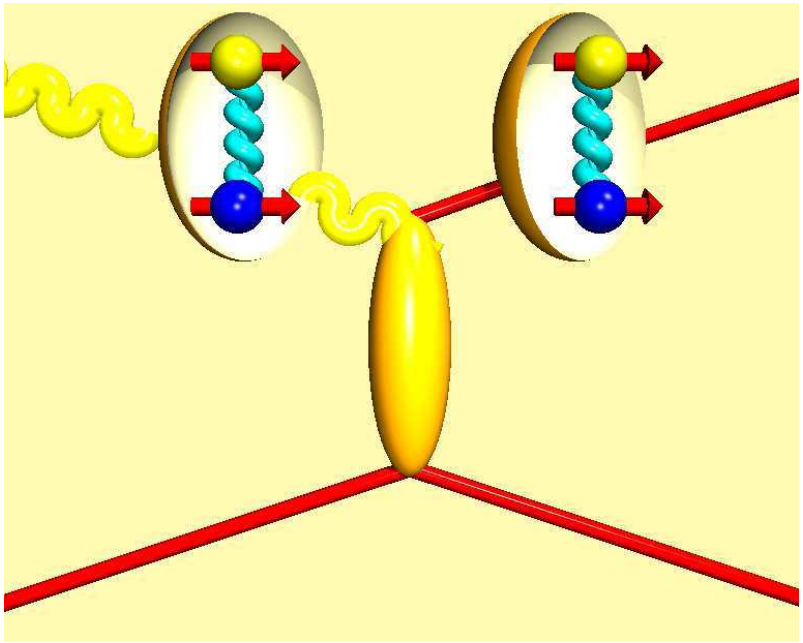

GlueX R&D at FSU
GLUE X CITATIONS PERIMENT

The Advantage of a Photon Beam



Pion Beam

- π with $S = 0$, $L = 0$ and $m = 1$
  ➜ $J^{PC} = 1^{++}, 1^{--}$
- Spin flip required for exotic quantum numbers



Photon Beam

- γ with $S = 1$, $L = 0$ and $m = 1$
  ➜ $J^{PC} = 0^{-+}, 0^{+-}, 1^{-+}, 1^{+-}, \ldots$
- No spin flip needed for exotic QN's

Summary

Very diverse group activities:

- Hardware developments for the GlueX Time-of-Flight detector
- Detector simulations and exploratory partial-wave analysis for GlueX
- Analysis of CLAS data:
  - $\gamma p \to N^* \to p + X$
    - ➜ Detector reconstruction, simulations, partial-wave analysis, theoretical approaches, ...
  - $\gamma p \to p + \text{Meson}$
    - ➜ Detector reconstruction, simulations, partial-wave analysis